War-Winning Capabilities … On Time, On Cost

Lessons Learned While Giving Unaugmented Airplanes to Augmentation-Dependent Pilots

20 Nov 2012

Bill Gray
USAF TPS/CP
Phone: 661-277-2761

Lessons Learned While Giving Unaugmented Airplanes to Augmentation-dependent Pilots

Bill Gray
Chief Test Pilot
USAF Test Pilot School

Thesis

- Modern technology, including fly-by-wire control systems with envelope protection have increased flight safety and effectiveness.
- Modern pilots are dependent upon these systems.
- Maintaining skills required to operate without these aids create an immense training burden.
- Ground-based simulators cannot duplicate the feel of loss-of-control scenarios.

Failure modes must preserve critical protections.


F-16


Pitts
S2B


T-6A


A-10

They all have sticks and rudders, right?

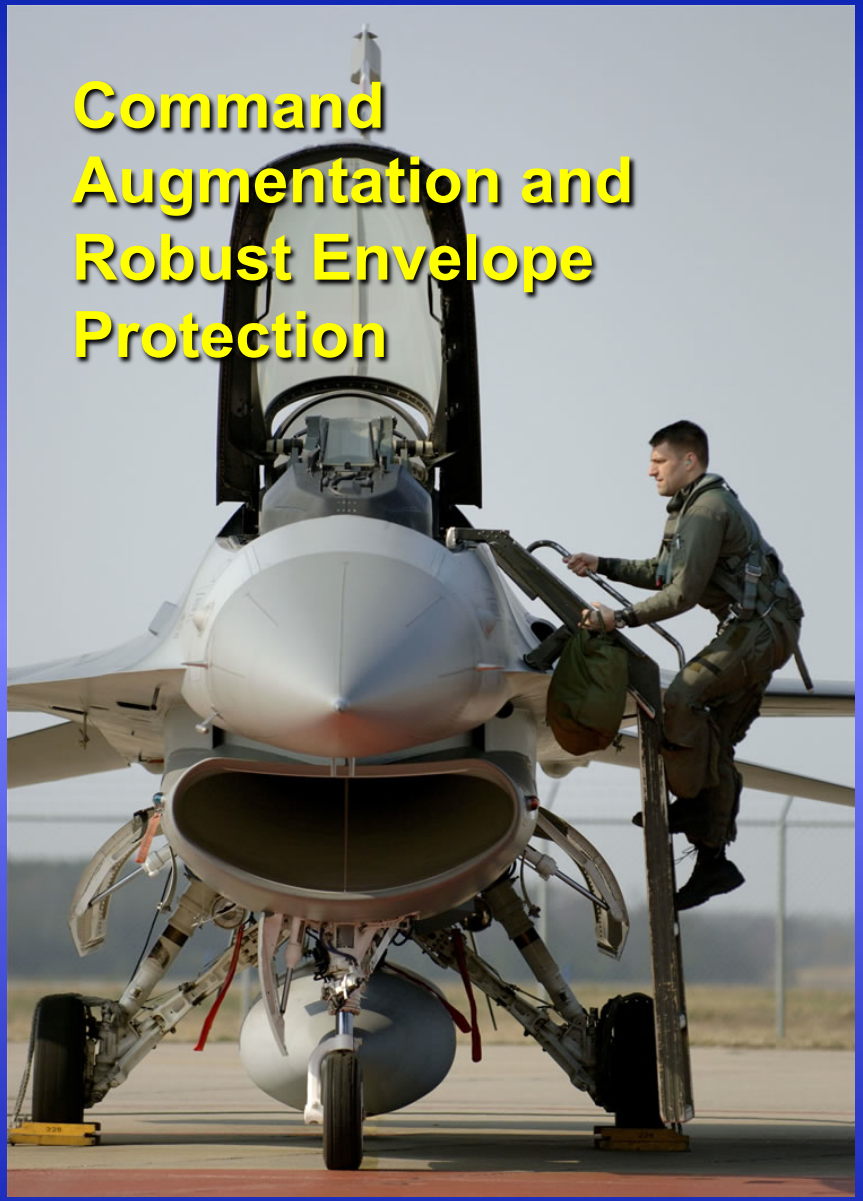
Scientia est Virtus

S2B, T-6, A-10

- The stick moves the elevator create a pitching moment
- The stick moves the ailerons to create a roll moment
- The pedals move the rudder to a create a yaw moment
- The airplane then responds as a function of its stability characteristics

F-16

- The stick provides a voltage to the digital flight control computer that interprets it either as a command for pitch rate or g, then moves the stabilators as required to produce the commanded result with a minimal delay or residual motion while ensuring that the aircraft exceeds neither angle-of-attack of g limitations.
- The stick provides a voltage to the digital flight control computer that interprets it as a command for roll rate—with the final rate determined by the aircraft configuration, airspeed, and angle-of-attack—then moves the flaperons, rudder, and stabilators as required to produce the commanded roll rate with minimal delay.
- The pedals provide a voltage to the digital flight control computer that interprets it as a command for a given amount of rudder deflection. Roll commands are overridden to some extent to ensure a normal feel (roll due to yaw, etc.). Rudder pedal commands are only necessary during ground operations and departure recovery.


Command
Augmentation and
Robust Envelope
Protection

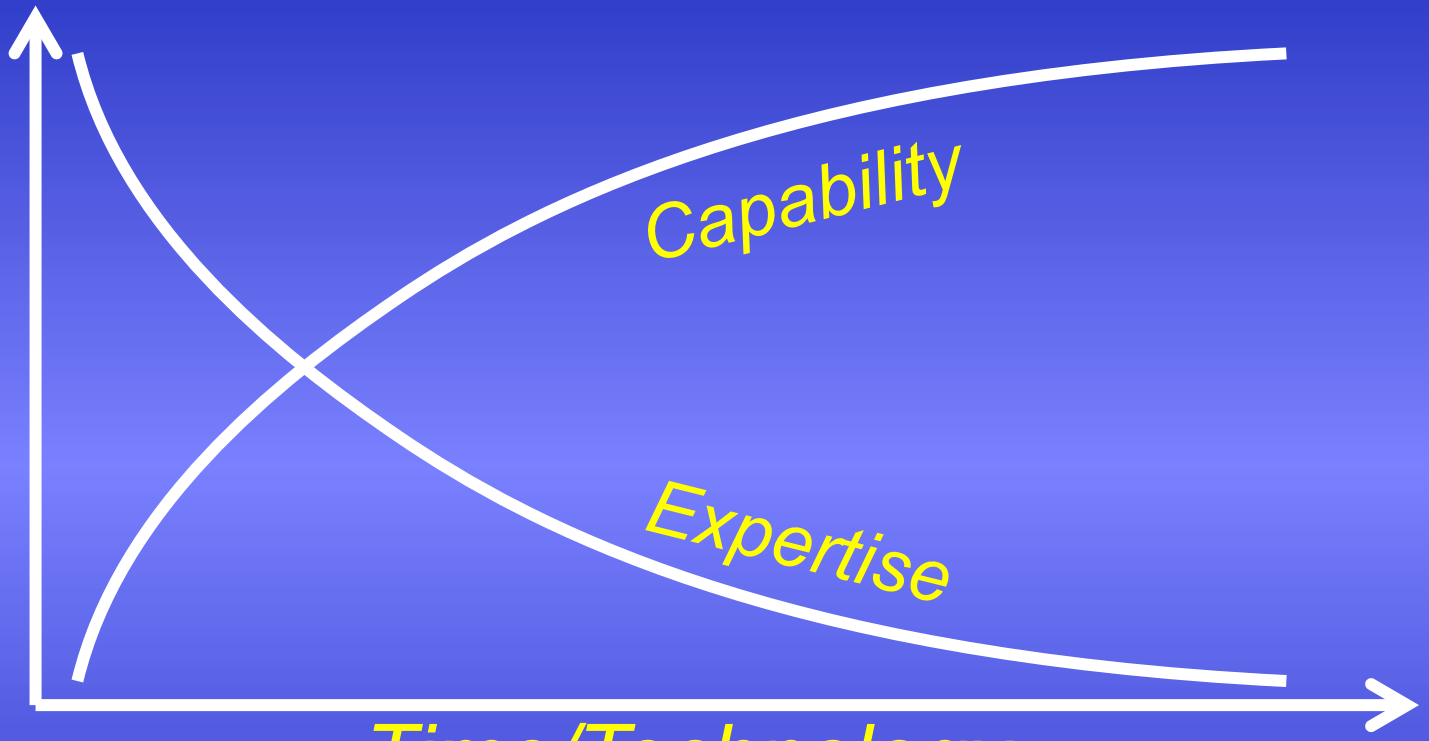

Ground Loop!


Ground Loop!


Departure and Spin!

Capability ≠ Expertise

Scientia est Virtus



Technologically Enabled Capability

Unaugmented Carrier Landings

Augmented Carrier Landings

Manual Reversion

NF-16D VISTA

More Reliance on Automation

- Moving maps
- Electronic engine controls
- Anti-skid brakes
- Stability and Control Augmentation
  - Dampers
  - Fly-by-wire
- GPS navigation
- Autopilots

Many modern pilots are primarily systems managers with minimal stick-and-rudder skills

What Happens When Automation is Lost?

Scientia est Virtus

- Surprise!
  - Subconscious reaction: Fly the airplane you were flying before the loss (may cause loss of control)
- If out of control: Reversion to training
  - Must be automatic: Increased training time
  - Must be appropriate: Increased training scenarios
- If in control and time allows: Reorientation
  - What is going on?
  - What do I have?

What is the training overhead to be prepared?

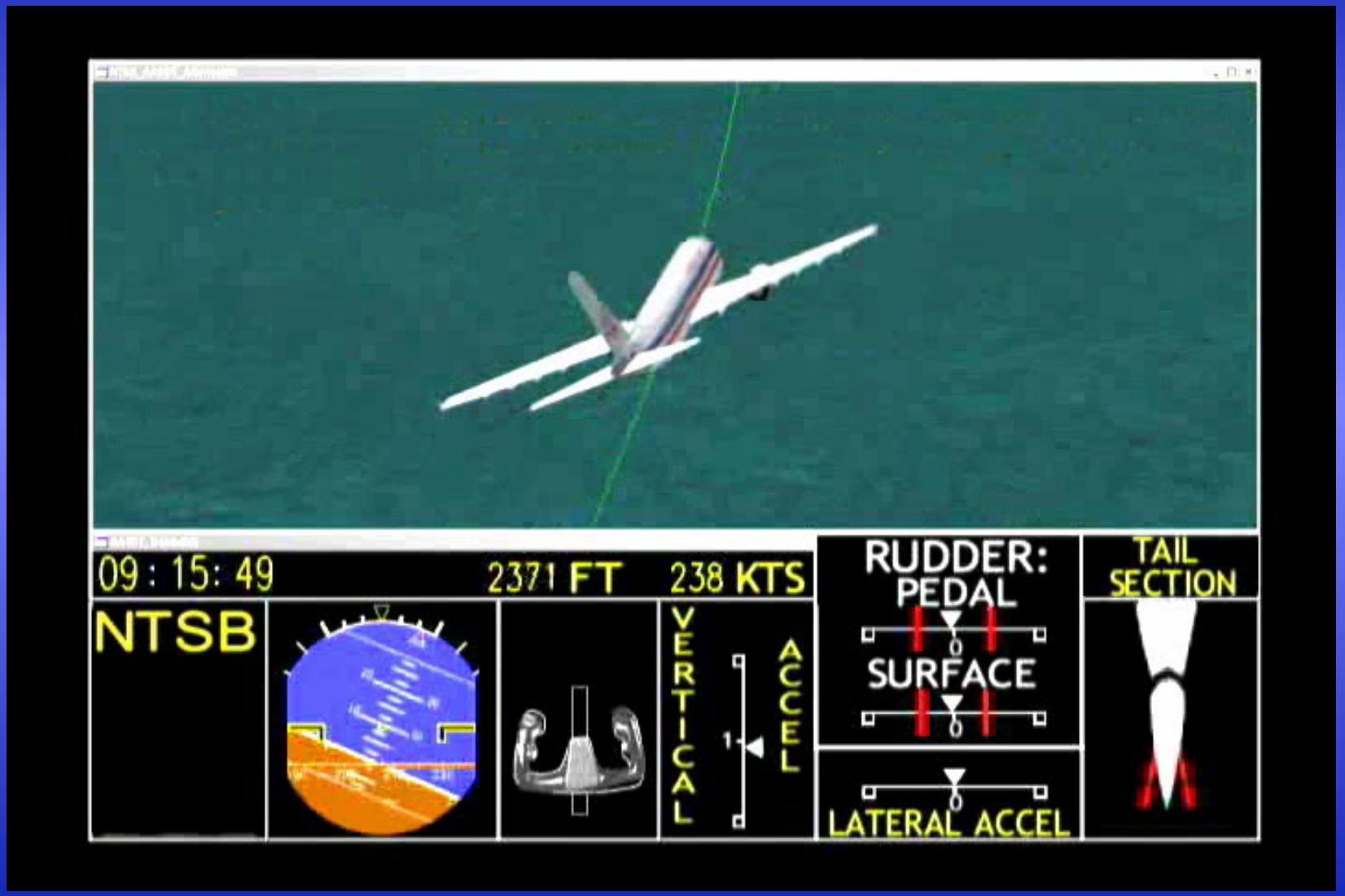
How About Simulators?

Scientia est Virtus

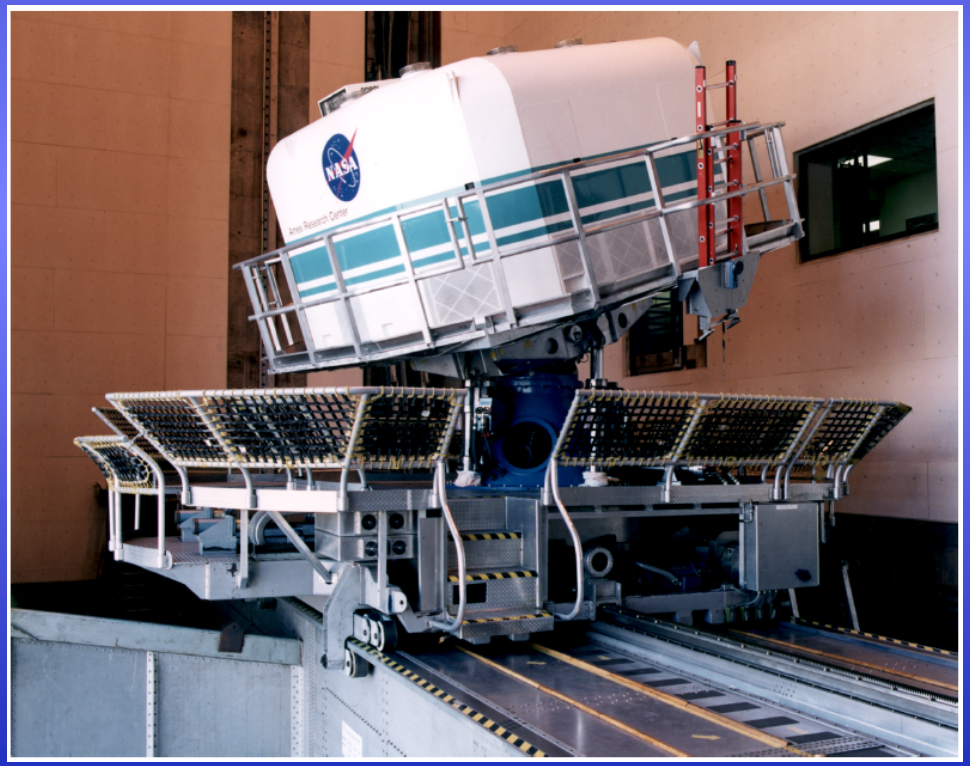
- Ground-based simulators cannot reproduce dynamic motions.
  - May encourage inappropriate control inputs
  - Pilots will be surprised by the feel of the real event
- Simulation models are much less accurate at the "edge of the envelope"
  - Surprises remain: *surprises are bad*
  - Pilots left to use trial-and-error in a real situation
  - Augmentation-dependent pilots have a small "tool kit"

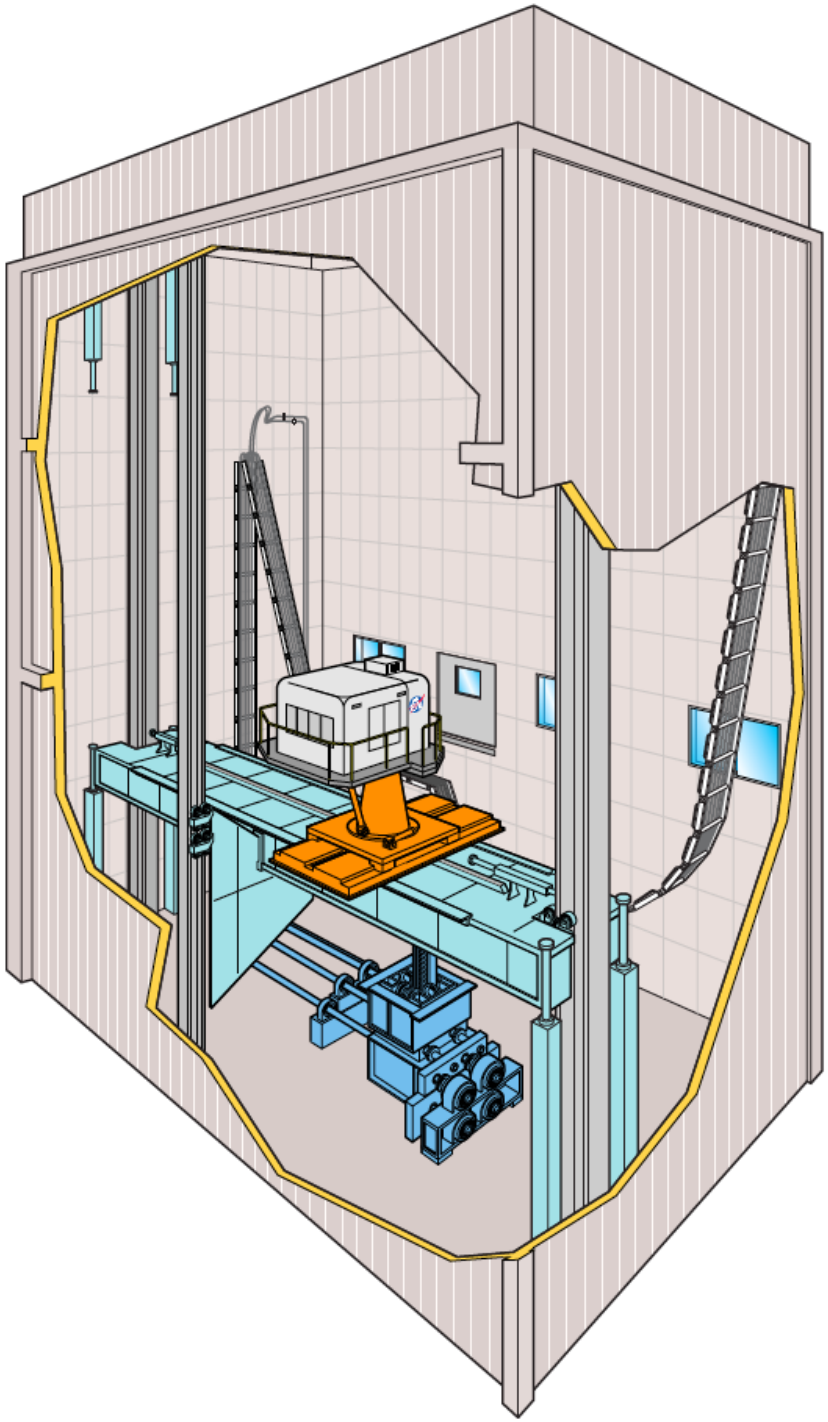
Let's have a case study…

AA587 Vertical Stabilizer Failure



NASA Ames Vertical Motion Simulator (VMS)





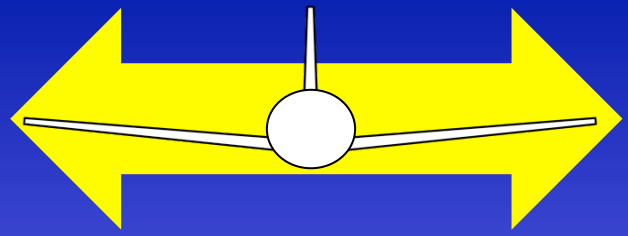
VMS Replication of AA587 Cockpit "Feel"

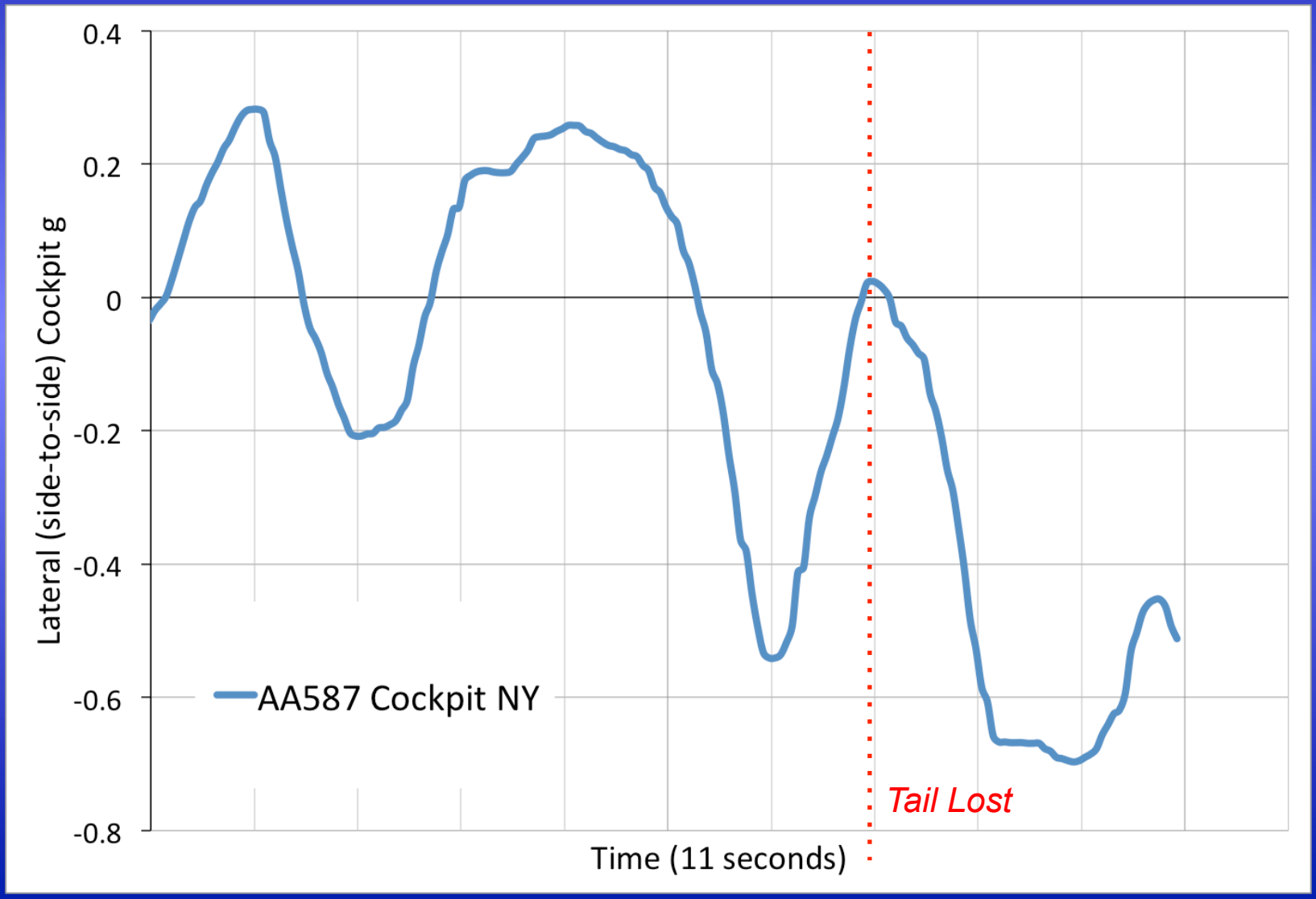
- Duplicated cockpit motion, control motion, and out-the-window view of the mishap.
- Eight pilot experts observed the mishap events in the cab.

"…sustained accelerations beyond the motion limitations of the VMS were not possible. However, Human Performance group members noted that the VMS was far better in its capability to produce realistic motion cues as compared to a typical hexapod motion-based training simulator."

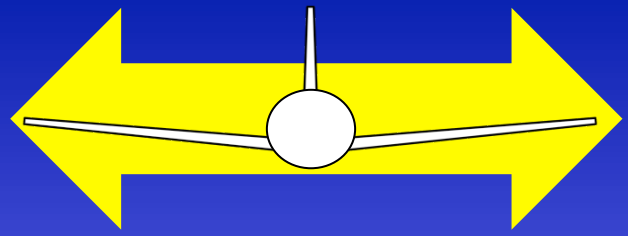
DCA02MA001 Human Performance Study Report

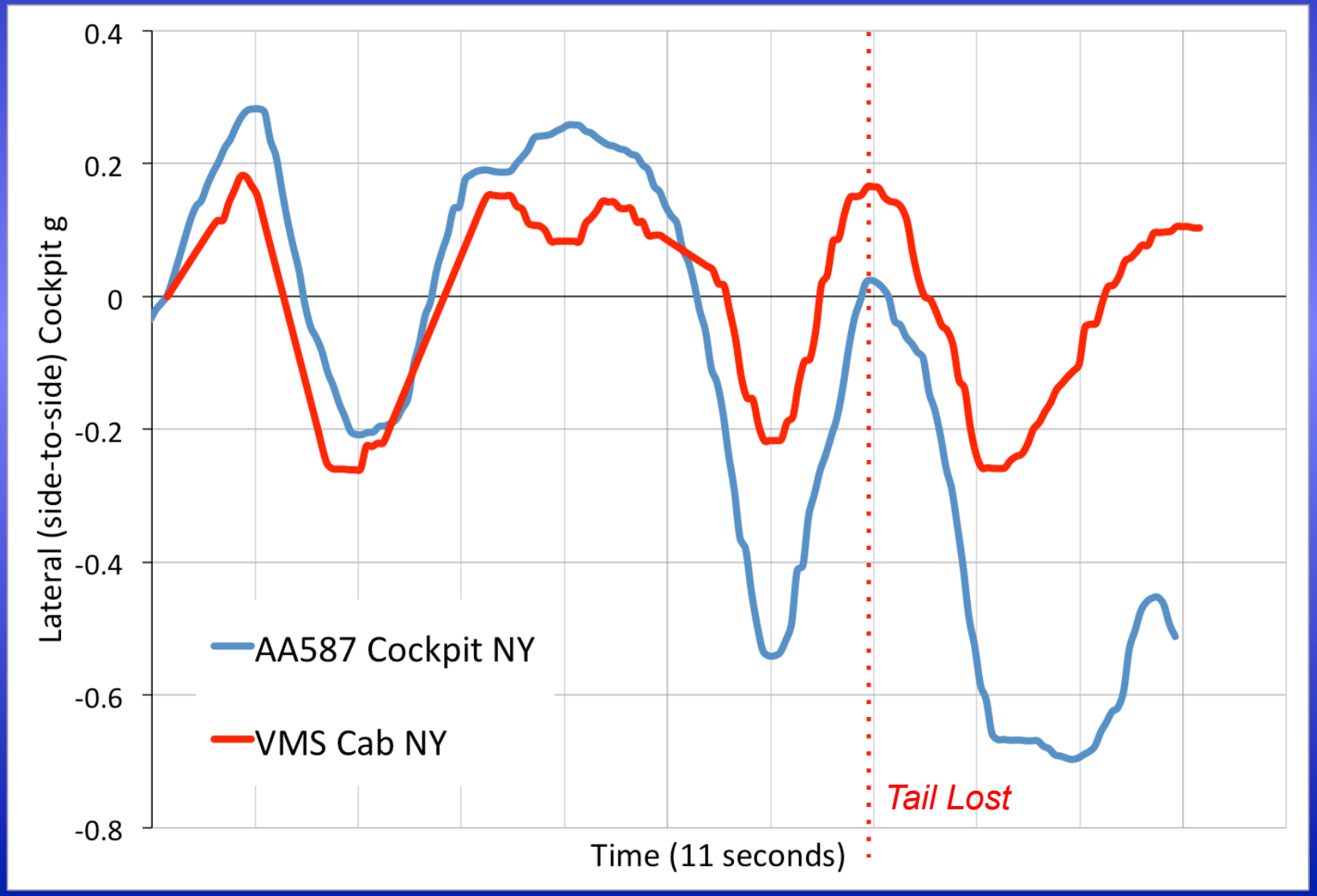
Lateral Acceleration



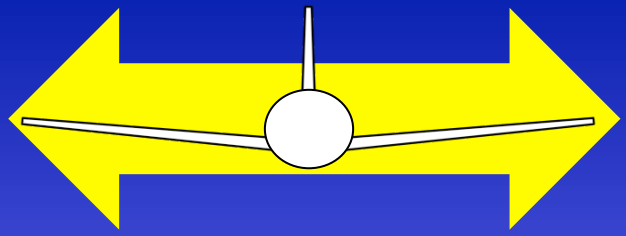


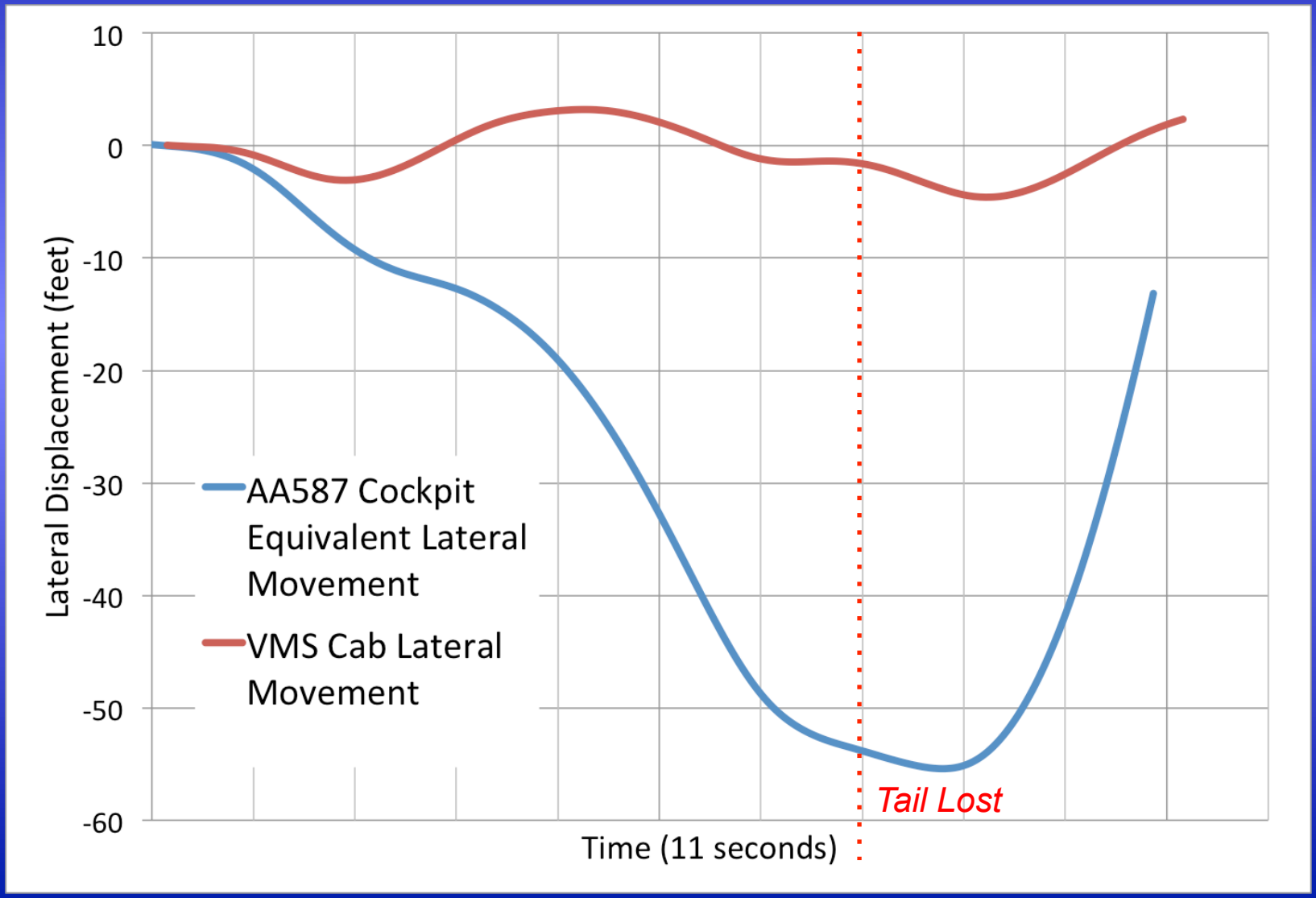
Lateral Acceleration



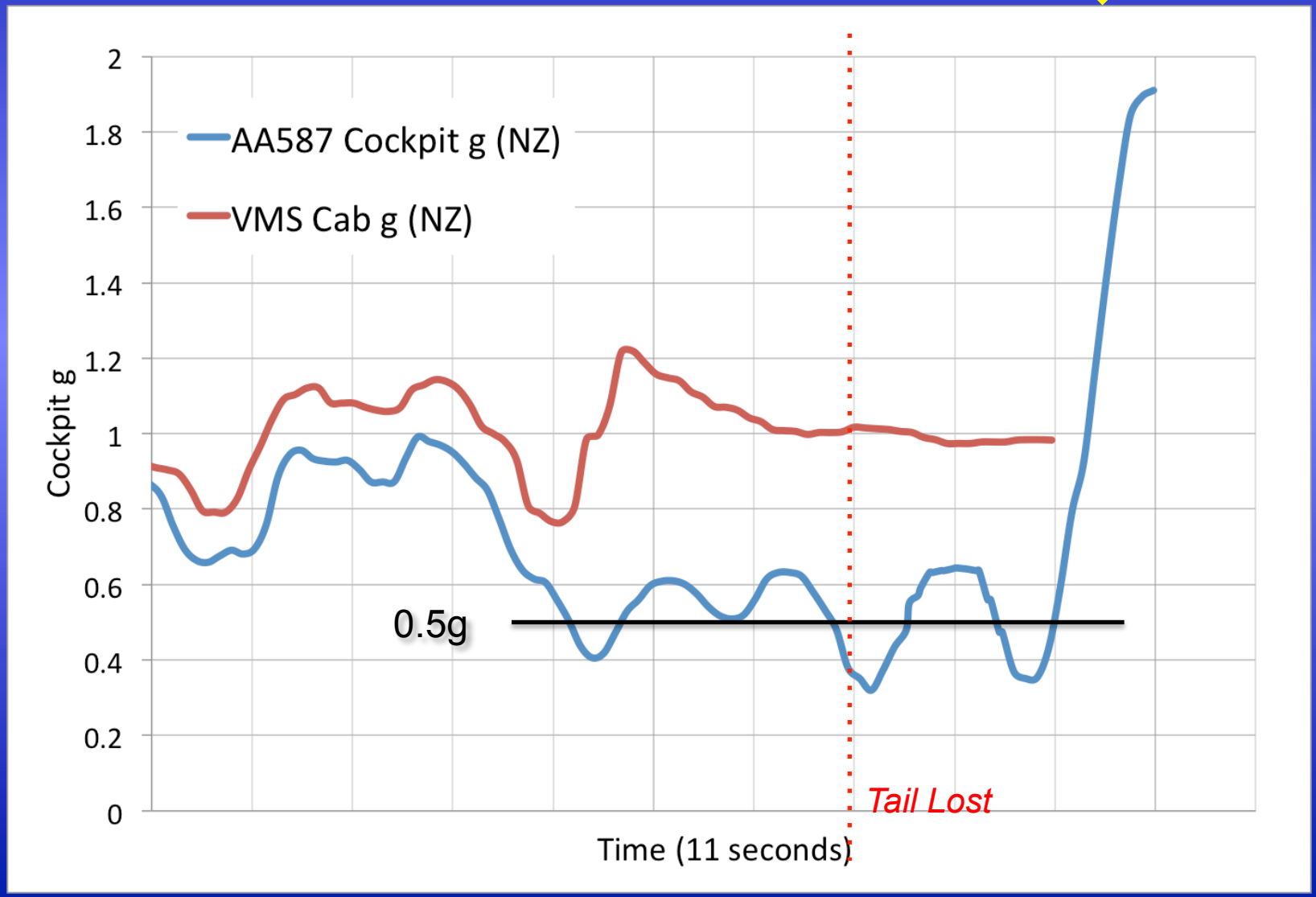


Lateral Displacement

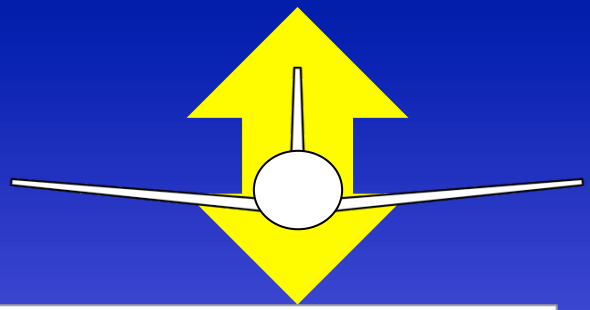


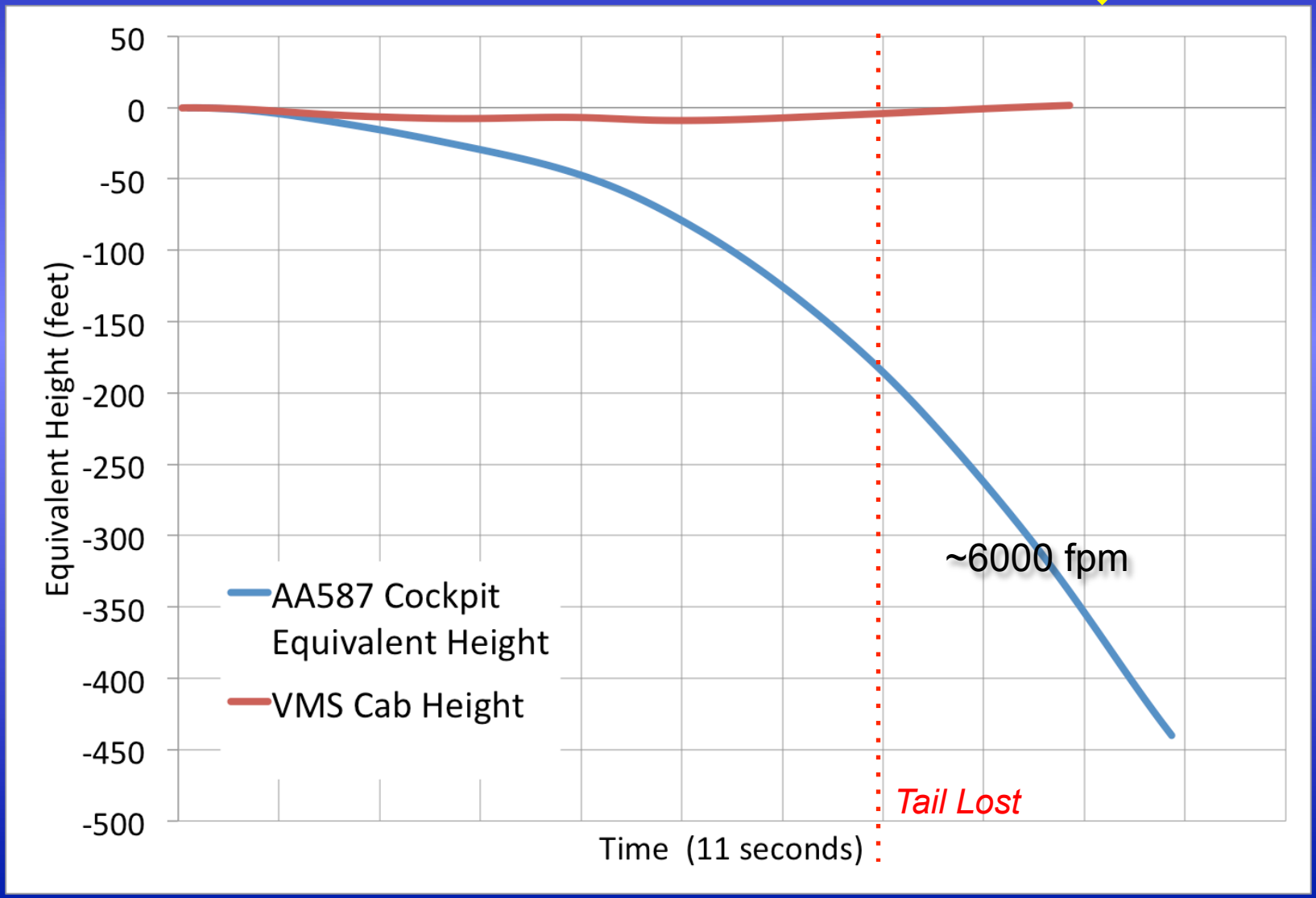


Cockpit g


2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Cockpit g
AA587 Cockpit g (NZ)
VMS Cab g (NZ)
0.5g
Tail Lost
Time (11 seconds)

Cockpit Displacement





So What?

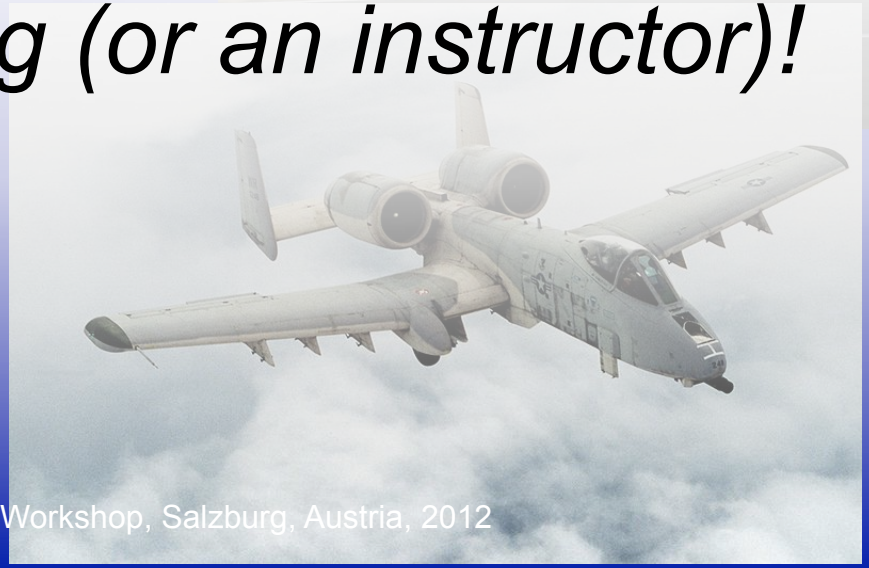
- The best ground-based simulator could not come close to reproducing the feeling in the cockpit of AA 487.
- A ground-based simulator can prepare a pilot for these motions is either impossible or very expensive.

Pilots subconsciously respond by "feel" during loss-of-control. Simulators cannot prepare them.

How About this Simulator?

Calspan NC-131H Total In-flight Simulator (TIFS), Retired 2009

We must not give a non-augmented or differently augmented aircraft to an augmentation-dependent pilot without appropriate training (or an instructor)!



Do Not Give a Pilot a New Aircraft During an Emergency

- Redundancy, redundancy, redundancy
  - Independent backups (hardware, software)
- Design for redundancy
  - Reduce complexity
  - Performance may suffer
  - Fault tolerance is vital
- Minimize motions that cannot be simulated
  - This is part of envelope protection
- Consider a fool-proof automated recovery system

Thesis

- Modern technology, including fly-by-wire control systems with envelope protection have increased flight safety and effectiveness.
- Modern pilots are dependent upon these systems.
- Maintaining skills required to operate without these aids create an immense training burden.
- Ground-based simulators cannot duplicate the feel of loss-of-control scenarios.

Failure modes must preserve critical protections.